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Harnessing Wind Vibration, a Novel Approach towards Electric Energy Generation - Review

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Abstract*: Vortex-Bladeless is a Spanish SME whose objective is to develop a new concept of wind turbine without blades called Vortex or vorticity wind turbine. This design represents a new paradigm in wind energy and aims to eliminate or reduce many of the existing problems in conventional generators. The bladeless vortex turbine is one such concept that uses the principle of aero-elasticity and thereby the variations produced by it to generate electricity. Project work will include the design and development of a vortex wind bladeless turbine and a gyro action based e-generator to be coupled to it to generate the electricity. Prototype development will be done using 3-D printing for the vortex turbine and the e-generator to make a scaled working model that will demonstrate electricity generation and testing will be done on the same to determine the effect of wind speed on , turbine speed , voltage , current and power generated by the model.*

Keywords: Vortex bladeless turbine, gyro torque, vortex shedding effect, wind turbine

I. INTRODUCTION

Vortex-Bladeless is an objective to develop a new concept of wind turbine without blades called Vortex or vortices wind turbine. The vortex design aims to eliminate or reduce many of the existing problems in conventional generators and represents a new paradigm of wind energy. It is morphologically simple and it is composed of a single structural component, so its manufacturing, transport, storage and installation have clear advantages. The new wind turbine design has no bearings, gears, etcetera, so the maintenance requirements could be drastically reduced and their lifespan is expected to be higher than traditional wind turbines. In the development of this new device, it is of prime importance to be able to test different geometrical configurations, operation conditions and to have energy production predictions.

II. MATERIALS AND METHODS

2.1 Material Required

Material required for the vortex bladeless turbine is fiberglass and carbon fiber mast oscillates in the wind taking advantage of the vortex shedding effect [1-5]. At the bottom of the mast a carbon fiber rod moves inside a linear alternator that generates the electricity, with no moving parts in contact. Vortex has a small carbon footprint, is noiseless, has low center of gravity and allows for small foundation dimensions, so more generators can be placed in an area, at twice the density of traditional turbines. What is a vortex? Vortex is a wind generator without blades. Instead of capturing energy via the rotational motion of a turbine, the Vortex takes advantage of what's known as vorticity, an aerodynamic effect that occurs when wind breaks against a solid structure. The Vortex structure starts to oscillate, and captures the energy that is produced. Vortex is just eliminating the blades[6-14]. They have designed it to have no parts like all (no gears, linkages,etc.). This way they can make Vortex cheap and easy to maintain. Basically, they reduce the amount of raw materials used for manufacturing, which cuts the production costs and time to produce the equipment. Further, having no moving parts in contact means that there are really very few things that can break, which extends time between maintenance intervals and allows to have less down time [15-24]. As a result, maintaining costs are low.
Working of a vortex bladeless turbine with a gyro e-generator, the main principle behind bladeless wind generator is the conversion of linear oscillation of the mast to rotational motion [25-40]. As the mast is subjected to wind energy, it tends to oscillate due to the vortices formed around the structure of the mast, which can be converted to rotational force

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togenerate electricity. In the bladeless wind system configuration, the mast is fixed with respect to the ground and the rib structure at the top of the mast consisting of thread arrangement is used for pulling the threads attached to it. Energy is obtained by continuous oscillation of the mast; the vibrations from the wind turbine are given to the e-gyro generator. Gyro Torque is a new type of infinitely variable transmission system based on gyroscopic reaction [40-60]. Gyro Torque is capable of large speed ratios, without the need to utilize gears for generating electricity from wind and wave power resources. The infinitely variable nature of gyro Torque means that more power from wind and wave sources can be captured and controlled to generate electricity at reduced costs. By not transmitting the peaks and troughs of wind gusts gyro Torque avoids severe mechanical and electrical loading from the turbine onto other parts of the system including the Generator.

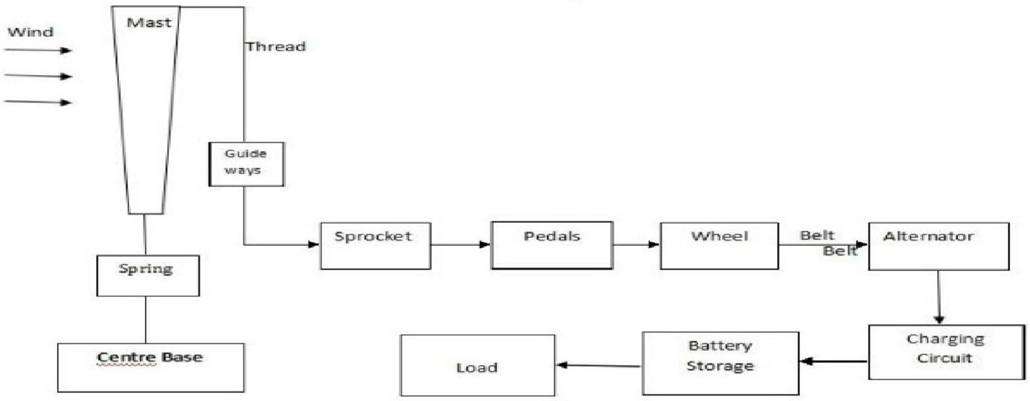

Fig. 2.1 Block Diagram Representation of Bladeless Power Generation Scheme

2.2 Vortices and Vortex Shedding Effect:

Vortex shedding is an oscillating flow that takes place when a fluid such as air or water flows past and bluffs (As opposed to streamlined body at curtained velocities, depending on shape and size of the body. In this vortices are created at the back of the body and detach periodically from either side of the body. Vortex shedding behind a circular cylinder. In this animation, the flows on two sides of a cylinder are shown in different colors.

2.3 Gyro Torque Technology:

Static: In the static type, the input torque is transmitted to the output by a ratio called a speed ratio, meaning that input is directly linked to the output via some form of physical constraint such as gears or belts. Kinetic: In the kinetic type, this does not occur; rather power transmission torque is generated within the transmission. This means that the input and output can move independently of each other with no physical constraint.Gyro Torque belongs to kinetic type

It consists of a gyroscopic rotor that is held in an inner ring (sub-frame), the latter being free to pivot in an outer ring (main-frame). The mainframe is free to rotate in transmission housing. The sub-frame is connected to the input mechanism by linkage (off-set pin), which pivot the sub-frame in the mainframe. The mainframe, the subframe and the linkage rotate together under the influence of gyroscopic reaction. The mainframe is connected to output (rotating shaft) and the transmission housing via one-way clutch. Ability to decouple and control the transmission with minimal effort for maintenance purposes and variable operation. Ability to operate two or more gyro Torque units in parallel if required to achieve high transmission capacity.

2.4 Types of vortex bladeless turbine:

Vortex Atlantis: 3 meters height and 100W generation capacity, working along with solar panels, mainly to bring energy to off grid locations. Vortex Mini: 13 meters height and 4 kW generation capacities, mainly for small-scale/residential wind. Vortex Grand: 150 meters height and 1 MW generation capacity, capable of generating electricity for 400 houses.

III. METHODOLOGY

3.1 VORTEX SHEDDING PATTERN

Vortex Shedding effect was first described and mathematically formalized by Theodore von Kármán, the genius of aeronautics, in 1911. This effect is produced by lateral forces of the wind on an object immersed in an exceedingly streamline flow. The wind flow generates a cyclical pattern of vortices, which act as challenges for slender structures, like towers, masts and chimneys. The thought behind Vortex turbine is that it's possible that very same behind Vortex turbine is that it's possible that very same forces are often exploited to supply energy. When the wind vortices match the natural frequency of the device'. The structure begins resonating, hence oscillating, so the bladeless turbine harnesses energy from that movement as an everyday generator. (Saurabh Bobde 2016) The Bladeless Windmill could also be an idea that works on the phenomenon of vortex shedding to capture the energy generated. Vortex shedding is an oscillating flow which occur when a fluid, like air or water, flows past a bluff (as against a streamlined) body at certain speeds, depending on the dimensions and shape of the body. This technology works by positioning cylindrical bodies in the natural flow of the wind. Flow over this cylinder produces an irregular vortex pattern that induces alternating high lifting forces on the body. Strouhal Number, St is a non-dimensional parameter that defines the output frequency of the vortex to the oscillating flow mechanism. Depending on the length of the mast, Frequency and torque of the system the Power output is obtained.

The Model VIV-driven Bladeless Wind Turbine requires fluid flow forces and structural force vibration model obtained by Navier – Stokes equations. The present study considers the 2–D CFD model for flow over the stationary cylinder diameter D of the Bladeless s Wind Turbine (Fig.3). The force factor in the flow direction is called drag. The normal force part of the flow is called the lift. A Comparative Computational Analysis between DES-SST and RANS-SST Model was performed, followed by a simulation modelling of two cylinders at a centre-to-center distance greater than 1.4 diameters to determine the Drag and Lift Coefficient. It is found that the RANS – SST model yields fluctuating CD and CL results, while the DES – SST gives convergent simulation results in a flow over a s stationary cylinder at Re = 105.The Euler-Bernoulli beam theory and the Galerkin method are used to derive a nonlinear distributedparameter model for the BWTs under a fluctuating lifting force due to periodic derailment of vortices. The derived dynamic model is validated by comparison with the 3D CFD-FEM numerical simulation. In BWTs, the periodic release of vortices in the air flow along the z-direction causes vibrations in the y-direction. The BWTs consist of a relatively long (right or conical) cylinder, which is either flexible or mounted on a flexible structure exposed to a uniform flow of air. The semi empirical model of the nonlinear wake oscillator was used to obtain an expression for the crosswise flow-induced fluctuating lifting force due to periodically discarding vortices.

3.2 VORTEX INDUCED VIBRATIONS

(Giosan and Eng 2000) When the wind blows through the slender structural portion, the vortex is alternately shed from one side to the other, giving rise to a fluctuating force acting at right angles to the wind direction. This structured pattern of vortexes is referred to as the von Karman vortex street. The phenomenon of the vortex shedding forces for circular cylinders is dependent on the Reynolds Number. Tubular, multi-sided or circular, tapered or non-tapered free-standing structures can be subject to significant dynamic stress caused by vortex shedding. In view of these aspects, the possibility of structural fatigue must be considered at the design stage. (Zheng et al. 2019) The wind-induced reactions of a thousand-metre-scale four-tower-connected mega-tall building was investigated using an aero-elastic model test to take into account the fluid-structure interaction associated with a large aerodynamic damping ratio. In addition, the critical wind speed for vortex-induced resonance and the lock-in area are calculated. At 60 degree wind direction, the rate of precipitation of the vortex increases steadily with the decreased wind velocity Vr and reaches the structural frequency.In both wind and wind directions, a large lock-in area is observed. The VIV-like phenomenon in the wind direction is combined with the vortex-induced resonance in the wind direction. This finding shows that there is aerodynamically coupled vortex shedding of a thousand-metre-scale four-tower-connected mega-tall building in the wind and wind directions. (Zuo and Letchford 2010) Traffic signal support systems with cantilevered mast arms are known to exhibit high-amplitude vibrations in such wind conditions. On the basis of full-scale measurements, the vibration of the cantilevered tapered traffic signal mast arm was studied. In-interpretation of vibration characteristics and their association with wind speed, it was discovered that, with traffic signals attached. The structure was sensitive to two kinds of vibration. At the low point wind speeds, the structure displayed large-scale vibrations due to the vortex shedding of the cantilevered limb. At high wind speed, the structure vibrated at amplitudes lower than those of the vortex-induced vibrations due to buffeting. (Transmission 2015) says that Vortex-induced vibration (VIV) is a common phenomenon in a wide variety of transmission line structures. Occasionally high conditions. On the basis of full-scale measurements, the vibration of the cantilevered tapered traffic signal mast arm was studied. In-interpretation of vibration characteristics and their association with wind speed, it was discovered that, with traffic signals attached. The structure was sensitive to two kinds of vibration. At the low point wind speeds, the structure displayed large-scale vibrations due to the vortex shedding of the cantilevered limb. At high wind speed, the structure vibrated at amplitudes lower than those of the vortex-induced vibrations due to buffeting. (Transmission 2015) says that Vortex-induced vibration (VIV) is a common phenomenon in a wide variety of transmission line structures. Occasionally high e for understanding natural frequencies and mode shapes, comparing these to Strouhal No. to warn of the resonant response to vortex spills at large wind speeds, and Scruton No. calculation to warn of extreme amplified response due to lock-in. Fatigue detailing may be necessary. Future design procedures should involve complex effects and resistance to fatigue. (Zahari and Dol 2014) The application of Vortex induced vibration to produce energy is a feasible alternative energy solution for offshore applications. VIV has the potential l to supply energy in a low-speed current area where traditional hydrokinetic applications are unable to work. Although the power output may be relatively poor, this technology is considered to be modern and can therefore be further improved in different segments. It's changed from time to time. With a current speed as low as 0.1 m / s, the VIV application designed is capable of delivering l to supply energy in a low-speed current area where traditional hydrokinetic applications are unable to work. Although the power output may be relatively poor, this technology is considered to be modern and can therefore be further improved in different segments. It's changed from time to time. With a current speed as low as 0.1 m / s, the VIV application designed is capable of delivering a rated power output as high as 10.4 W with a single array. When such an application farm is built, the power supply can be increased and different industries, ranging from offshore platforms and even land-based Operations can be assisted.

Vortex-induced vibrations (VIV) of a rigid cylinder inclined to the oncoming flow is not studied as extensively as the case of a normal-incidence cylinder, despite its applications in the offshore risers, mooring lines of the floating offshore wind turbines and subsea pipelines, to name a few, where the flow direction may not always be perpendicular to the long axis of the structure. Extensive studies on VIV of flexibly-mounted rigid cylinders placed normal to the oncoming flow exist and many comprehensive review papers have been published (e.g., Bearman, 1984, Sarpkaya, 2004, Williamson and Govardhan, 2004, Vandiver, 2012). Vortex-induced vibrations of flexible cylinders placed normal to the flow have been studied extensively as well (e.g., Wu et al., 2012, Bourguet et al., 2011, Bourguet et al., 2012, Modarres-Sadeghi et al., 2010, Modarres-Sadeghi et al., 2011).

In the case of cylinders inclined to the oncoming flow, an existing hypothesis – called the Independence Principle (IP) and mainly used for the fixed cylinders – states that the inclined cylinders can be treated as the normal-incidence ones, if only the component of the free stream velocity normal to the cylinder axis is considered. This approach neglects the effect of the axial component of the flow velocity, which is legit for small angles of inclination, but not when the angle of inclination increases. The angle of inclination is defined as the angle between the cylinder axis and the plane normal to the oncoming flow. When a cylinder is placed at an angle of inclination of θ, the axial component of the oncoming flow is $U \sin \theta$ and its normal component is $U \cos \theta$. Zero angle of inclination corresponds to a cylinder perpendicular to the oncoming flow. A cylinder inclined away from the oncoming flow is considered to have a positive angle of inclination and otherwise.

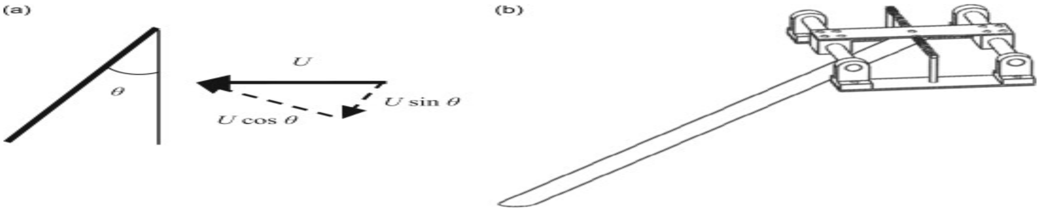

Fig. 3.1. (a) An inclined cylinder placed in flow along with the normal and axial components of flow velocity and (b) a schematic of the experimental set-up

For a fixed inclined rigid cylinder, studies conducted by Surry and Surry (1967), Van Atta (1968), Ramberg (1983), Kozakiewicz et al. (1995), Thakur et al. (2004), Yeo and Jones (2008) and Zhao et al. (2009) among others suggest that the cylinder behaves similarly to a normal-incidence cylinder up to an inclination of around 40–50°. Lam et al., 2010, Lam et al., 2012 investigated the influence of waviness on the flow past a fixed yawed cylinder using large eddy simulation. In the case of a flexibly-mounted inclined cylinder, experimental (Hanson, 1966, Ramberg, 1983, Franzini et al., 2009) and numerical studies (Lucor and Karniadakis, 2003, Willden and Guerbi, 2010) have been conducted to study the IP based on the Strouhal number (St), drag coefficient (C_D) and the angle of vortex shedding.Van Atta (1968) investigated angles of inclination within the range of $50° \leq \theta \leq 75°$ on hot wires. He confirmed that large oscillations could be seen for such high angles and that the maximum-amplitude region lies in the normalized reduced velocity ($U^{\square}_{n}=U\cos\theta/f_N D$) range of 5.8–6.4. King (1977) justified taking the component of the flow velocity ($U\cos\theta$) to calculate the reduced velocity and drag forces by performing flow visualization tests. He demonstrated that flow over –34° in-line oscillating inclined cylinder was normal to the cylinder axis. The existence of the axial flow was also evident and itwas different in the case of positively and negatively inclined cylinders. Positive angles of inclination lead the flow to move downward in the wake of the cylinder, and negative angles caused the flow to move upward. He also showed that the inclined cylinders response was identical for positive and negative angles of inclination ($-45° < \theta < 45°$). Ramberg (1983) studied the effect of the angle of inclination on circular cylinders forced to vibrate in a Reynolds number range of 160–460. He observed parallel vortex shedding till $\theta=50°$ and summarized that the end conditions dominate the flow around an inclined cylinder.Lucor and Karniadakis (2003) performed direct numerical simulation (DNS) to validate the IP for stationery and freely vibrating rigid cylinders. They considered angles of inclinations of $\theta=–60°$ and –70° in a cylinder with a mass-damping coefficient of $m^{\square}\zeta=0.006$ and an aspect ratio (L/D) of 22 at a constant Reynolds number: Re=1000. They observed that for the larger inclination, the maximum amplitude response decreases ($A^{\square}=0.63$ for –60° and $A^{\square}=0.52$ for –70°). They also showed that for both angles of inclination, the maximum amplitude lies in the range of normalized reduced velocities, $U^{\square}_{n}$, stated by King (1977) and Ramberg (1983). For a freely vibrating cylinder, the vortex shedding was parallel to the cylinder axis. In addition, they found that the drag forces were higher than predicted by the IP.Franzini et al. (2009) performed experiments on inclined cylinders free to oscillate in the crossflow direction till $\theta=45°$ and observed that the lock-in occurs in the same normalized reduced velocity range as stated by King (1977) and Ramberg (1983). Finally, Willden and Guerbi (2010) performed forced oscillation tests across a range of oscillating frequencies (f/f_S) at a fixed amplitude of oscillation ($A/D=0.3$), emphasizing on the variation of the component of the lift coefficient in phase with the cylinder′s velocity C_{Lv}. For $\theta=60°$, they observed two excitation regimes: The first wider regime around $f/f_S=0.75$ resulted in parallel vortex shedding, and the second small regime around $f/f_S=1$ resulted in slantwise vortex shedding.

In the present study, a series of experiments were conducted on a flexibly-mounted inclined rigid cylinder up to an angle of inclination of θ=75° in the Reynolds range of Re=500–4000 to study the influence of inclination on the resulting vortex-induced vibrations by focusing on the displacement and frequency responses.

IV. INTRODUCTION OF EXPERIMENTAL SET-UP

The experiments were performed in a re-circulating water tunnel with a test-section of 1.27 m×0.50 m×0.38 m and a turbulence intensity of less than 1% up to a flow velocity of 0.3 m/s. To reduce the damping in the system, two air bearings were mounted on two rigid parallel shafts located atop the water tunnel test-section, resulting in a one-degree-of-freedom system with oscillations in the crossflow direction only (Fig. 1(b)).

The natural frequency (fN) of the system was measured by performing a decay test in water and found to be fN=0.93 Hz. The structural damping coefficient (ζ) of the system was found, using a decay test in air, to be ζ=0.0045 and the mass ratio (m□=4m/πρD2L, where m is the mass of the cylinder per unit length, L the cylinder length, and ρ the flow density) of the cylinder to be m□=6.5, leading to a mass-damping coefficient of m□ζ=0.029 for all angles of inclination. The mass of the system included the mass of the cylinder and the moving objects such as the air bearings and the supporting plate for mounting the cylinder. Solid aluminum cylinders with a diameter (D) of 12.7 mm were machined to achieve the desired inclination such that for each cylinder, the lower end was cut parallel to the test-section floor. Cylinders with θ=0°, 20°, 45°, 55°, 65° and 75° were tested. The immersed aspect ratio (Li/D) of the cylinders was kept constant at approximately 29 for every angle of inclination.

The end conditions of the cylinder play an important role in the observed VIV response as demonstrated by Morse et al. (2008) for a vertical cylinder. For a vertical or inclined cylinder partially submerged in water, the upper end of the cylinder is in contact with the free surface and the lower end is submerged in water. The free surface does not influence the parallel vortex shedding (Khalak and Williamson, 1996) but the lower end of the cylinder can induce three-dimensionality into the flow. The experiments here were performed on cylinders with an unattached streamlined endplate (25 cm×36 cm) placed with a gap of 1 mm (0.08D) at the lower end of the cylinder. The end plate was held at a specific height using two vertical supports attached to its two sides. The gap size was chosen because for a normal-incidence cylinder, a gap size smaller than 15% of the cylinder diameter results in a behavior similar to a cylinder with an attached endplate – i.e., negligible three-dimensional effects due to the end condition – without increasing the moving mass due to the attached endplate (Morse et al., 2008). Flow visualization was conducted on the endplate to make sure that no major separation was resulted by the endplate′s leading edge. The displacement was measured using a Micro-Epsilon (ILD 1402-600) non-contacting laser sensor. For each inclination, the water level was held constant and the flow velocity was increased from zero in small steps. At each step, the amplitude and frequency of oscillations were calculated using the recorded displacement time series and the reduced velocity was calculated as U□=U/fND.

V. RESULTS AND DISCUSSION

The result shoe that the vortex bladeless turbine is Installation cost and maintenance cost low compared to blade wind mill, It produces less noise compared to blade wind mill, It occupies less area. High efficient power is generated. the generation of electricity is made possible by the small structure of bladeless turbine. This project will satisfy the need of continuous generation of electricity. The overall project uses less space area hence highly economical for the ru

VI. DISCUSSION

Thus we have discussed about the innovative of Bladeless Wind Turbine using Vortex Effect, and the impacts of wind induced vibration over slender structures by vortex shedding effect. It is understood that though the slender structures get prone to fatigue due to vortex street , they can be optimised and cylindrical structure like high mast pole can be synthesized to function as a bladeless turbine as the shredding frequency obtained from them will be efficient to produce energy. They also minimize the wake effect produced in conventional turbine. However future study is to be made to understand about the relationship between mass of the structure and vortex induced vibration. energy.

VII. CONCLUSION

The bladeless wind generation system configuration has been considered and the obtained results appear to be very encouraging, even though they are based on simulations and model taken from the literature, which certainly can give only approximate description of involved dynamics. Tapping the wind for renewable energy using new approaches is gaining momentum in the recent years. The purpose of this paper is to provide some fundamental results on the bladeless wind system and serve as stepping stones for the future development of bladeless wind power generating system. The forces that is beneficial or useful to generate power in bladeless are different from those in conventional horizontal axial wind turbines. Our device captures the energy of vorticity, an aerodynamic effect that has plagued structural engineers and architects for ages (vortex shedding effect). As the wind bypasses a fixed structure, its flow changes and generates a cyclical pattern of vortices. Overall the project has been a success with all of the project requirements achieved.

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